Contents

Information for Teachers

Student Activities

Acknowledgements

August 11, 2000
July 11, 2001
Boulder, Colorado

I extend my sincere appreciation to the many individuals who helped to prepare *SAM-II - Student Activities in Meteorology*. The willingness of many National Oceanic and Atmospheric Administration's (NOAA) employees to spend time and effort and to share their knowledge provides the strong scientific basis for the *SAM-II* series.

To the many teachers who use the original *Student Activities in Meteorology - SAM*, I thank you. Because of you, *SAM* is in its third printing and successful way beyond our original aspirations. I hope that you find *SAM-II* as useful.

My gratitude goes to the American Meteorological Society (AMS) for their positive reviews of *SAM*. Because of AMS, *SAM* received very valuable, national attention. To Rhonda Lange, I owe a special note of thanks for providing the inspiration and opportunity to write *SAM-II*. Through Rhonda, NOAA's Forecast Systems Laboratory provided many of the support services necessary during the draft writing of *SAM-II*. Many thanks to Holly Rosales who joined our team as a student intern and provided fast and efficient research and computer support.

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Sincerely,

Beverly L. Meier

Beverly L. Meier
Science Teacher – Boulder Valley School District

SAM II Pre-2

Letter to Colleagues in Science and Teachers

August 11, 2000
July 11, 2001
July, 16, 2002
Boulder, Colorado

Scientists from NOAA's research laboratories in Boulder and Seattle have joined me in collaborating for a second time to produce a series of classroom science activities on meteorology, and atmospheric and oceanic science. We call this second series *Student Activities in Meteorology-II* or *SAM-II*. As with the original *SAM*, our goal is to provide activities that are interesting to students, and at the same time convenient and easy to use for teachers.

The topics that we chose are designed so that students use trend setting scientific research and cutting edge technology to learn the processes of science - data collecting, graphing, analyzing, predicting, etc. - as well as information, principles, and concepts of science. In *SAM-II*, we included an oceanography activity to address the global effects of the atmosphere-ocean connection.

We believe that these activities are versatile and can be easily integrated into your current science, environmental studies, health and safety, social studies, and math curriculum. A grid that shows how *SAM-II* conforms to the National Science Education Content Standards is included.

Also, please notice the Website addresses included in *SAM-II*. Some of the student activities are based on information that is available as website data or information. Students who are familiar with the Internet might enjoy comparing the results of their procedure to that of the researchers. Other students may find more information on the topics that appear in *SAM-II*.

Although each *SAM-II* activity can be used alone, the series is designed to supplement your established curriculum. Three activities, "Anatomy of Clouds", "Disappearing Ozone", and "Greenhouse Effect", have two procedures. In each case, the first procedure is less difficult and can be done independently of the second procedure.

The activity, "Forecasting Tornados", uses a complicated looking graph called a Skew-T diagram: yet, eighth graders, who had previous graphing experience, quickly mastered the diagonal graphing strategy during our field test.

We have included an updated version of the "Greenhouse Effect" from the original *SAM*. This newer version includes a wealth of historical data including the currently available carbon dioxide and methane concentrations. For all of *SAM-II*, we tried to create activities that are both useful and flexible enough to adapt to different teaching and classroom styles.

SAM II Pre-3

Letter to Colleagues in Science and Teachers

(Continued)

Furthermore, these activities are designed to span a wide range of grade and ability levels. The reading level is aimed at grades 7 - 10. All middle school and older students should be able to complete the procedures.

The questions that follow each procedure vary in difficulty and can challenge high school students. By design, easier questions are at the beginning followed by more difficult questions toward the end of the question section. A serious attempt was made to incorporate math into the procedures and follow-up questions.

All *SAM-II* activities are well-suited for small group instruction, individual student work, and independent study. The activities have also been updated as of July 16, 2002 with some minor changes based on their first use in my classes. We hope that you find these activities flexible enough to adapt to your teaching and classroom style.

We hope that these activities prove to be interesting and motivational, and provide a spring-board to lively classroom discussions.

Sincerely,

Beverly L. Meier

Beverly L. Meier
Science Teacher – Boulder Valley School District

National Science Education Content Standards

These standards are based on the recommendation made in 1996 by the National Research Council in their publication, National Science Education Standards. The standards included here are those specifically targeted for middle and high school students.

		1	2	3	4	5	6	7	8	9	10	11	12
GRADES 5 to 8	**Scientific Inquiry**												
	* Identify questions that can be answered through scientific investigations.	✓	✓	✓	✓	✓	✓						
	* Design and conduct a scientific investigation.	✓											
	* Use appropriate tools and techniques to gather, analyze, and interpret data.												
	* Develop descriptions, explanations, predictions, and models using evidence.	✓	✓	✓	✓	✓	✓						
	* Think critically and logically to make the relationships between evidence and explanations.	✓	✓	✓	✓	✓	✓						
	* Recognize and analyze alternative explanations and predictions.					✓	✓						
	* Communicate scientific procedures and explanations.	✓	✓	✓	✓	✓	✓						
	* Use mathematics in all aspects of scientific inquiry.	✓	✓	✓	✓	✓	✓						
GRADES 9 to 12	* Identify questions and concepts that guide scientific investigations.	✓	✓	✓	✓	✓	✓						
	* Design and conduct scientific investigations.	✓											
	*Use technology and mathematics to improve investigations and communications.	✓	✓	✓	✓	✓	✓						
	* Formulate and revise scientific explanations and models using logic and evidence.					✓	✓						
	* Recognize and analyze alternative explanations and models.					✓	✓						
	* Communicate and defend a scientific argument.	✓	✓	✓	✓	✓	✓						

SAM II Pre-5

Standards
(continued)

		1	2	3	4	5	6	7	8	9	10	11	12
GRADES 5 to 8	**Physical Science**												
	* Understand properties and changes of properties in matter.	✓	✓	✓	✓	✓	✓						
	* Understand the concepts of motions and forces.	✓	✓		✓	✓							
	* Understand the concept of transfer of energy.	✓	✓		✓	✓	✓						
GRADES 9 to 12	* Understand the structure of atoms.			✓			✓						
	* Understand the structure and properties of matter.	✓	✓	✓	✓	✓	✓						
	* Understand the concepts of chemical reactions.			✓									
	Understand the concept of motion and forces.	✓	✓		✓	✓							
	* Understand the concepts of concentration of energy and increase in disorder.	✓	✓		✓	✓	✓						
	* Understand the concept of interactions of energy and matter.	✓	✓	✓	✓	✓	✓						
GRADES 5 to 8	**Life Science**												
	* Understand structure and function in living systems.			✓		✓	✓						
	* Understand reproduction and heredity.												
	* Understand regulation and behavior.					✓	✓						
	* Understand populations and ecosystems.					✓	✓						
	* Understand diversity and adaptations of organisms.					✓	✓						
GRADES 9 to 12	* Understand the cell.												
	* Understand the molecular basis of heredity.												
	* Understand the concept of biological evolution.												
	* Understand interdependence of organisms.					✓	✓						
	* Understand the concepts of matter, energy, and organization in living systems.					✓	✓						
	* Understand the behavior of organisms.					✓							

SAM II Pre-6

Standards (continued)

		1	2	3	4	5	6	7	8	9	10	11	12
GRADES 5 to 8	**Earth and Space Science**												
	* Understand structure of the Earth System.	✓	✓	✓	✓	✓	✓						
	* Understand Earth's history.						✓						
	* Understand Earth in the solar system.						✓						
GRADES 9 to 12	* Understand the energy in the Earth system.		✓		✓	✓	✓						
	* Understand the geochemical cycles.			✓			✓						
	* Understand the origin and evolution of the Earth System.												
	* Understand the origin and evolution of the Universe.												
GRADES 5 to 12	**Science and Technology**												
	Develop abilities of technological design.	✓	✓	✓	✓	✓	✓						
	* Develop the understanding about science and technology.	✓	✓	✓	✓	✓	✓						
	Science in Personal and Social Perspectives												
GRADES 5 to 8	* Understand personal health.			✓									
	* Understand populations, resources, and environments.		✓	✓	✓	✓	✓						
	* Understand natural hazards.		✓	✓	✓	✓	✓						
	* Understand risks and benefits.		✓	✓	✓	✓	✓						
	* Understand science and technology in society.	✓	✓	✓	✓	✓	✓						
GRADES 9 to 12	* Understand personal and community health.			✓									
	* Understand population growth.												
	* Understand natural resources.					✓							
	* Understand environmental quality.	✓	✓	✓	✓	✓	✓						
	* Understand natural and human-induced hazards.	✓	✓	✓	✓	✓	✓						

SAM II Pre-7

Standards
(continued)

		1	2	3	4	5	6	7	8	9	10	11	12
GRADES 9 to 12	**Science in Personal and Social Perspectives *(continued)***												
	* Understand science and technology in local, national, and global challenges.	✓	✓	✓	✓	✓	✓						
GRADES 5 to 8	**History and Nature of Science**												
	* Understand science as a human endeavor.	✓	✓	✓	✓	✓	✓						
	* Understand nature of science.	✓	✓	✓	✓	✓	✓						
	* Understand the history of science.			✓		✓							
GRADES 9 to 12	* Understand Science as a human endeavor.	✓	✓	✓	✓	✓	✓						
	* Understand the nature of scientific knowledge.	✓	✓	✓	✓	✓	✓						
	* Understand the historical perspectives.		✓	✓	✓	✓	✓						

SAM II Web Site Addresses

The web sites listed on the following four pages provide a wealth of additional information on the subjects presented in SAM II activities 1 - 6. The levels of additional information provided in these sites range from beginning to very advanced, allowing students of all levels to research additional meaningful material on the SAM II subjects.

As of Fall 2001, all the following web sites are active. However, they are subject to change and may not all be available when students begin their work with the SAM II activities.

If too many of these sites are no longer active, the developers and creators of SAM and SAM II recommend using the World Wide Web search engine "Google."

http://www.google.com/

Enter "Google" using key words from each SAM II activity. The following table gives a sample of key words to use in entering the "Google" search engine.

Activity 1	Clouds, Environmental Technology Laboratory, NOAA
Activity 2	GPS, Hurricane Georges, Forecast Systems Laboratory, National Hurricane Center, NOAA
Activity 3	Ozone, Ozone Hole, NASA, Aeronomy Laboratory, NOAA
Activity 4	Tornados, Skew-T, National Severe Storms Laboratory, NOAA
Activity 5	El Niño, La Niña, Pacific Marine Environmental Laboratory, NOAA
Activity 6	Greenhouse Effect, Global Warming, Climate Monitoring and Diagnostics Laboratory, NOAA

SAM: *The original SAM, published in 1993, can be found in the following URL*

- **http://www.fsl.noaa.gov/~osborn/sam/SAM_Intro.html**

SAM-II: *The six new activities listed as follows on this page (under construction as of Fall 2003)*

- **http://www.fsl.noaa.gov/~osborn/samii/SAM_II_Intro.html**

Activity 1: *Anatomy Of Clouds*

- **http://www.etl.noaa.gov**
- **http://www.etl.noaa.gov/25anniv/radar/**
- **http://www6.etl.noaa.gov/pdj/img/wisp_06mar91.0602.jpg**

SAM II Pre-9

SAM II Web Site Addresses SAM II
(continued)

Activity 2: *Forecasting Severe Weather: Forecasters Use GPS to Observe a Hurricane (Hurricane Georges)*

- **http://oak.fsl.noaa.gov/gps.html**
- **http://gpsmet.fsl.noaa.gov/realtimeview/jsp/rti.jsp**
- **http://lwf.ncdc.noaa.gov/oa/reports/georges/georges.html**
- **http://www.publicaffairs.noaa.gov/stories/sir19b.html**
- **http://www.srh.noaa.gov/sju/georges.html**
- **http://gps.faa.gov/index.htm**
- **http://www.garmin.com/aboutGPS/**
- **http://www.gpsworld.com/resources/glossary.htm**
- **http://www.cosmic.ucar.edu/gpsmet/**
- **http://www.navtechgps.com/glossary.asp**

Activity 3: *Disappearing Ozone*

- **http://www.ozonelayer.noaa.gov/**
- **http://www.al.noaa.gov**
- **http://www.cmdl.noaa.gov/ozwv/ozsondes/spo/index.html**
- **http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/ozone_hole.html**
- **http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/ATM_CHEM/chlorine.html**
- **http://science.nasa.gov/headlines/y2000/ast02oct_1.htm**
- **http://www.epa.gov/ozone/**
- **http://www.atm.ch.cam.ac.uk/tour/index.html**
- **http://www.nerc-bas.ac.uk/public/icd/jds/ozone/**
- **http://www.solcomhouse.com/OzoneHole.htm**

Activity 4: *Forecasting Tornados: Forecasters Use Temperature, Dewpoint, and Air Pressure (Skew-T)*

- **http://www.fsl.noaa.gov/**
- **http://meteora.ucsd.edu/wx_pages/upper_air.html**
- **http://cimss.ssec.wisc.edu/goes/misc/990503.html**
- **http://twister.sbs.ohio-state.edu/helpdocs/skew_T_help.html**
- **http://weather.uwyo.edu/upperair/sounding.html**
- **http://weather.unisys.com/upper_air/skew/index.html**
- **http://www.met.tamu.edu/personnel/students/weather/soundings/**
- **http://twister.sbs.ohio-state.edu/skewt.html**
- **http://www.rap.ucar.edu/weather/upper/**

SAM II
Pre-10

SAM II Web Site Addresses SAM II
(continued)

Activity 5: *El Niño and La Niña*

- **http://www.elnino.noaa.gov/**
- **http://www.elnino.noaa.gov/lanina.html**
- **http://www.pmel.noaa.gov/**
- **http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html**
- **http://www.pmel.noaa.gov/tao/elnino/nino-home.html**
- **http://www.pmel.noaa.gov/tao/realtime.html**
- **http://www.cnn.com/SPECIALS/el.nino/strange.brew/**
- **http://go.hrw.com/atlas/norm_htm/spacific.htm**
- **http://www.usatoday.com/weather/nino/wnino0.htm**

Activity 6: *Greenhouse Effect - Too Much, Too Little, or Just Right?*

- **http://www.cmdl.noaa.gov/climate.html**
- **http://www.cdc.noaa.gov/glance/images/timeline.gif**
- **http://www.ngdc.noaa.gov/paleo/globalwarming/greeneffect.html**
- **http://www.epa.gov/globalwarming/climate/**
- **http://www.gcrio.org/ocp96/p30box.html**
- **http://www.dar.csiro.au/info/material/info98_2.htm**
- **http://www.greenhouse.gov.au/pubs/factsheets/fs_effect.html**
- **http://icp.giss.nasa.gov/research/methane/greenhouse.html**
- **http://www.pbs.org/wgbh/nova/ice/greenhouse.html**
- **http://www.greenpeace.org/~climate/science/reports/climatefaq.html**
- **http://earthguide.ucsd.edu/earthguide/diagrams/greenhouse/greenhouse.html**
- **http://katipo.niwa.cri.nz/ClimateFuture/Greenhouse.htm**
- **http://www.meto.umd.edu/~owen/CHPI/IMAGES/greeneff.html**
- **http://www.science.org.au/nova/016/016key.htm**
- **http://www.geocities.com/Athens/Forum/4821/**
- **http://www.enfo.ie/Library/fs/fs16.htm**
- **http://www.grida.no/climate/vital/03.htm**
- **http://www.crystalinks.com/greenhouseeffect.html**
- **http://www.geog.ouc.bc.ca/physgeog/contents/7h.html**
- **http://www.whrc.org/globalwarming/warmingearth.htm**
- **http://www.ucar.edu/learn/1_3_1.htm**

Note: Other educational activities by *SAM* and *SAM II* developer Beverly Meier - **Space Science Institute: *Solarscapes***

- **http://www.spacescience.org/Education/ResourcesForEducators/CurriculumMaterials/Solarscapes/1.html**

SAM II Pre-11

Answer Key

Activity #1 - Anatomy of Clouds

Part A

1. Varies
2. Varies
3. Varies
4. Varies
5. Varies

   Example: Low clouds tend to be darker gray than high clouds.

6. Thin, diffuse clouds are likely to be high, cirrus clouds that contain ice crystals; whereas, heavier, thick clouds are likely to be lower clouds that contain water.
7. Varies - Since scientific inquiry is a goal of Science National Content Standards, encourage students to design an investigation.

Part B

Reflectivity Radar Image

1. 10 km
2. 2 km
3. 2 and part of another
4. a. 6 - 8 km
   b. 1 - 2 km
   c. Approximately 2 km
   d. Approximately 6 km
5. 3.5 - 4.5 km
6. * The parts of the cloud colored red move the slowest. The faster moving parts of the cloud appear to be “tumbling” or falling over the slower moving parts.
   * Different layers of the atmosphere become mixed. Mixing affects the growth of water droplets or ice crystals, therefore cloud formation and weather.

Velocity Radar Image

1. Purple: 21 to 24 m/s
   Red: 17 to 20 m/s

   Note: negative sign indicates direction

SAM II Pre-12

Answer Key
(continued)

2. 90 Degrees
3. 5 – 10 m/s
4. 5 – 14 m/s
5. Buffeted by the wind; “bumpy” ride
6. 32.4 m.p.h.

Activity #2 - Forecasting Severe Weather: Forecasters Use GPS to Observe a Hurricane

1. September 28, 1998, 06:15 AM
2. September 28, 1998, 06:15 AM
3. The amount of precipitable water increases as surface air pressure decreases.
4. Improves short term forecasts, especially for severe weather. (Knowing that more water vapor is present, means that a storm is more likely.)
5. Low cost, improves reliability for predicting precipitation amount, high accuracy, operates under a variety of conditions such as cloudy and windy weather, can provide long-term climate monitoring, will help to save lives and property during severe weather.
6. The spike represents a visible “arm” of Hurricane Georges that reaches land before the full force of the hurricane.
7. Hurricane Georges gains power as it slowly builds up over water. It loses power quickly once it reaches land because there is no water to fuel it.
8. Hurricanes Georges increases in power, therefore in wind speed, as it gets its energy from the ocean (convection) over which it travels, then loses its source of energy as it travels over land, and therefore decreases wind speed.

Activity #3 - Disappearing Ozone

Part A

1. Oxygen molecule that contains three atoms of oxygen held together in the shape of the letter “V”
2. Chlorofluorocarbons, chemicals that are used as coolants for refrigerators and air conditioners, and for products such as beverage cups and insulation for houses, help to break apart ozone molecules.
3. (- 70.2°C)
4. 13.86 mPa
5. 16 km
6. Stratosphere

Answer Key
(continued)

7. Humans use chemicals that rise through the troposphere into the stratosphere.
8. Based on the graph, about 15%- 20%. However, the actual amount is closer to 10%. Since our atmosphere extends to about 50 km, not 38 km for the data used on this graph, there is a higher total amount of ozone in the atmosphere than is plotted.
9. Harmful: In the troposphere, it is a component of smog, damages plants and animals, contributes to greenhouse gases.
   Helpful: In the stratosphere, it filters ultraviolet radiation that can cause cancer and cataracts, as well as cause harm to food crops and other plants and animals.
10. Some Examples: Using styrofoam products and automobile air conditioners, disposing of refrigerators without removing the coolant.

Part B

1. Nitrogen, hydrogen and chlorine compounds that humans have added to our atmosphere. For example, chlorofluorocarbons break apart chlorine atoms.
2. Without the protection of ozone, plants and animals are harmed or die.
3. · Concentration of ozone decreased as the concentration of chlorine monoxide increased.
   · Chlorofluorocarbons probably cause the decrease in ozone.
4. An international agreement among governments to cut and phase out production of CFCs.
5. Some examples:
   · Will CFC substitutes contribute to the ozone loss?
   · How much do natural particles affect ozone destruction?
   · How will the ozone “hole” affect world weather and climate?

Activity #4 - Forecasting Tornados: Forecasters Use Temperature, Dewpoint, and Air Pressure

1. Temperature: 23°C
   Dewpoint: 17°C
   Wet air
2. Air pressure decreases as altitude increases .
3. Normally, temperature decreases as altitude increases in the troposphere.
4. Temperature decreases as altitude increases except between 820 mb and 795 mb where the temperature increases (temperature inversion).
5. About 625 mb
6. From ground level to about 825 mb.

Answer Key
(continued)

7. Decreases - Dewpoint temperature decreases and the distance between the temperature curve and the dewpoint curve increases.
8. About 220 mb to 200 mb
9. About 0.05°C per mb
10. There is no measurable moisture.
11. Between 609 mb and 533 mb
12. Temperature increases - Temperature inversion
13. Temperature inversion causes a ceiling. The temperature layer above the clouds is warmer and prevents air from rising, cooling, and condensing.

Activity #5 - El Niño and La Niña

1. Between 150W and 100W (more exactly 140W)
2. 160E
3. Blowing wind piles up the warm surface water in the direction that it is blowing toward.
4. East
5. Figure 5.3, the warmest water layer is almost level instead of being deeper in the western Pacific. There is more than usual warm water in the eastern Pacific near South America.
6. Figure 5.4, the warmest water is piled up in the western Pacific toward south-east Asia and Australia with cooler water in the eastern Pacific near South America.
7. 140E, 150E, 160E, 170E, 180; southeast Asia and Australia; warm water is deeper, therefore evaporation increases, then clouds form and storms increase.
8. 120W, 110W, 100W, 90W; South America; since the warm surface water has been blown westward, cold water nutrients rise and attract fish looking for food.
9. 140E, 150E, 160E, 170E, 180; west Pacific (southeast Asia, Australia); warm water that causes convection, and therefore, cloud formation and storms, has moved eastward away from Asia and Australia.
10. 2001 - 2002
11. Both are part of the ENSO cycle: influenced by the ocean-atmosphere system, recurring, cause convection, cause drought, cause storms and flooding, have global effects.
12. The thermocline levels out during an El Niño event and becomes steep during a La Niña event.
13. Some examples:
    - How accurate are El Niño and La Niña forecasts?
    - What deep ocean changes might affect El Niño and La Niña events?
    - Beside sea surface temperature changes, what other factors might predict El Niño and La Niña Events?

Answer Key
(continued)

Activity #6 - Greenhouse Effect

Part A

1. Northern Hemisphere winter
2. Southern Hemisphere winter
3. Less vegetation in the Southern Hemisphere, further from sources and sinks.
4. To avoid local contamination and to find an air average over large areas.

Part B

1. Increase
2. CH_4 - CH_4 increases 7.9 ppb per year, whereas CO_2 increases 1.5 ppm per year. Therefore, the rate of change for CH_4 is greater in one year.
3. No. Trace gas concentration is only one component of global warming. Need more information over a longer period of time, for example, “Is the global average temperature actually rising compared to natural variability?”

   The rate of change for CO_2 is 1.5 ppm/year.
   The rate of change for CH_4 is 7.9 ppb/year.